

# Series H: Hierarchy Guidelines



H3

BEST PRACTICE  
GUIDELINE

## Water Reuse and Reclamation

*Best Practice Guidelines for Water Resource Protection in the South African Mining Industry*

**DIRECTORATE: RESOURCE PROTECTION & WASTE**



**water & forestry**

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## DOCUMENT INDEX

This document is the third in a series of the following Hierarchy Best Practice Guideline documents:

BPG H1: Integrated Mine Water Management

BPG H2: Pollution Prevention and Minimization of Impacts

***BPG H3: Water Reuse and Reclamation***

BPG H4: Water Treatment

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Since 1999 a number of steering committee meetings and stakeholder workshops were held at various stages of the development and drafting of this series of Best Practice Guidelines for Water Resource Protection in the South African Mining Industry.

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**APPROVALS**

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## PREFACE

Water is typically the prime environmental medium (besides air) that is affected by mining activities. Mining adversely affects water quality and poses a significant risk to South Africa's water resources. Mining operations can further substantially alter the hydrological and topographical characteristics of the mining areas and subsequently affect the surface runoff, soil moisture, evapo-transpiration and groundwater behaviour. Failure to manage impacts on water resources (surface and groundwater) in an acceptable manner throughout the life-of-mine and post-closure, on both a local and regional scale, will result in the mining industry finding it increasingly difficult to obtain community and government support for existing and future projects. Consequently, sound management practices to prevent or minimise water pollution are fundamental for mining operations to be sustainable.

Pro-active management of environmental impacts is required from the outset of mining activities. Internationally, principles of sustainable environmental management have developed rapidly in the past few years. Locally the Department of Water Affairs and Forestry (DWAF) and the mining industry have made major strides together in developing principles and approaches for the effective management of water within the industry. This has largely been achieved through the establishment of joint structures where problems have been discussed and addressed through co-operation.

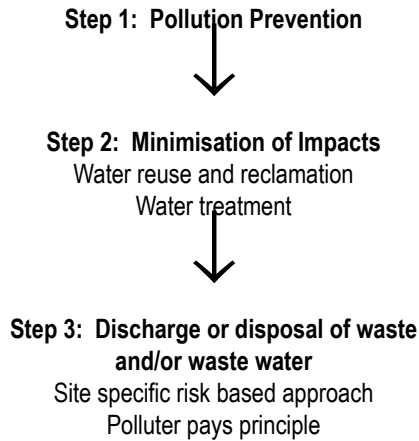
The Bill of Rights in the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) enshrines the concept of sustainability; specifying rights regarding the environment, water, access to information and just administrative action. These rights and other requirements are further legislated through the National Water Act (NWA), 1998 (Act 36 of 1998). The latter is the primary statute providing the legal basis for water management in South Africa and has to ensure ecological integrity, economic growth and social equity when managing and using water. Use of water for mining and related activities is also regulated through regulations that were updated after the promulgation of the NWA (Government Notice No. GN704 dated 4 June 1999).

The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat). The IWRM approach provides for both resource directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment. Examples of resource directed actions are the formulation of resource quality objectives and the development of associated strategies to ensure ongoing attainment of these objectives; catchment management strategies and the establishment of catchment management agencies (CMAs) to implement these strategies.

On the other hand, source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms.

The integration of resource and source directed measures forms the basis of the **hierarchy of decision-taking** aimed at protecting the resource from waste impacts. This hierarchy is based on a *precautionary approach* and the following order of priority for mine water and waste management decisions and/or actions is applicable:

## RESOURCE PROTECTION AND WASTE MANAGEMENT HIERARCHY



The documentation describing **Water Resource Protection and Waste Management** in South Africa is being developed at a number of different levels, as

described and illustrated in the schematic diagram below.

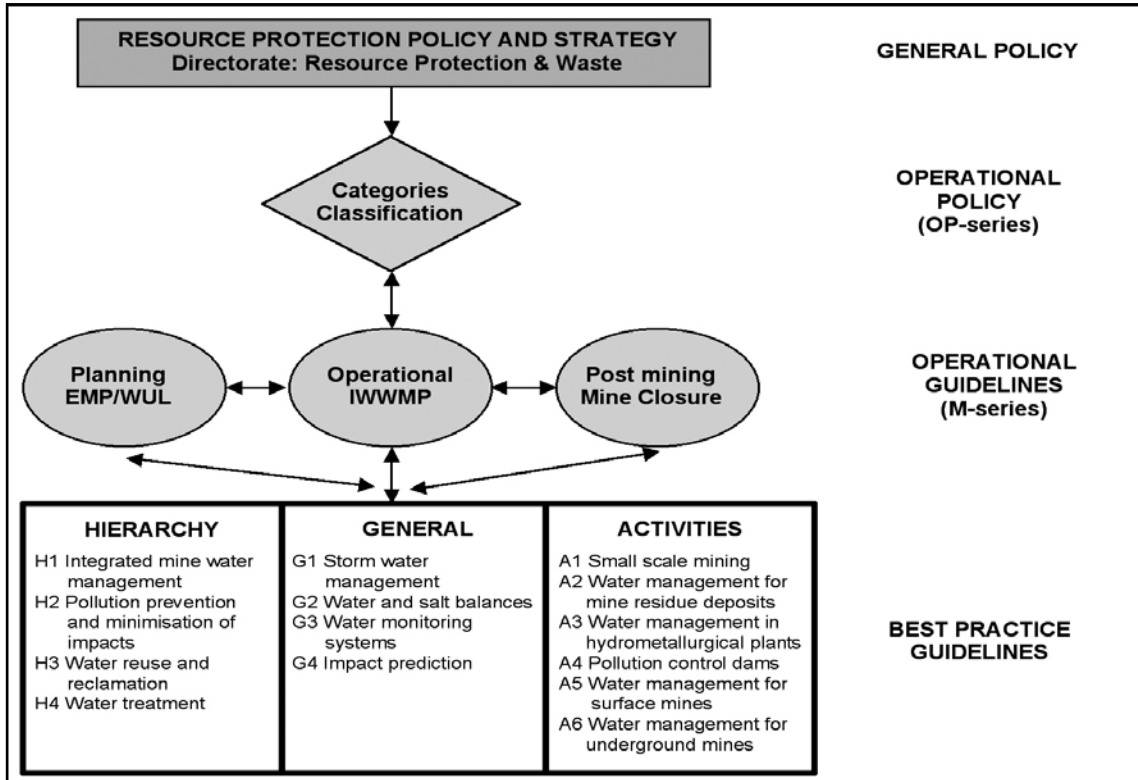
**The overall Resource Protection and Waste Management Policy** sets out the interpretation of policy and legal principles as well as functional and organisational arrangements for resource protection and waste management in South Africa.

**Operational policies** describe the rules applicable to different categories and aspects relating to waste discharge and disposal activities. Such activities from the mining sector are categorised and classified, based on their potential risks to the water environment.

**Operational Guidelines** contain the requirements for specific documents e.g. licence application reports.

**Best Practice Guidelines (BPG's)** define and document best practices for water and waste management.

## Schematic Diagram of the Mining Sector Resource Protection and Waste Management Strategy



The DWAF has developed a series of **Best Practice Guidelines (BPGs)** for mines in line with International Principles and Approaches towards sustainability. The series of BPGs have been grouped as outlined below:

**BEST PRACTICE GUIDELINES** dealing with aspects of DWAF's water management **HIERARCHY** are prefaced with the letter **H**. The topics that are covered in these guidelines include:

- H1 Integrated Mine Water Management
- H2 Pollution Prevention and Minimisation of Impacts
- H3 Water Reuse And Reclamation
- H4 Water Treatment

**BEST PRACTICE GUIDELINES** dealing with **GENERAL** water management strategies, techniques and tools, which could be applied cross-sectoral and always prefaced by the letter **G**. The topics that are covered in these guidelines include:

- G1 Storm Water Management
- G2 Water and Salt Balances
- G3 Water Monitoring Systems
- G4 Impact Prediction

**BEST PRACTICE GUIDELINES** dealing with specific mining **ACTIVITIES** or **ASPECTS** and always prefaced by the letter **A**. These guidelines address the prevention and management of impacts from:

- A1 Small-scale mining
- A2 Water Management for Mine Residue Deposits
- A3 Water Management in Hydrometallurgical Plants
- A4 Pollution Control Dams
- A5 Water Management for Surface Mines
- A6 Water Management for Underground Mines

The development of the guidelines is an inclusive consultative process that incorporates the input from a wide range of experts, including specialists within and outside the mining industry and government. The process of identifying which BPGs to prepare, who should participate in the preparation and consultative processes, and the approval of the BPGs was managed by a Project Steering Committee (PSC) with representation by key role-players.

The BPGs will perform the following functions within the hierarchy of decision making:

- Utilisation by the mining sector as input for compiling water use licence applications (and other legally required documents such as EMPs, EIAs, closure plans, etc.) and for drafting licence conditions.
- Serve as a uniform basis for negotiations through the licensing process prescribed by the NWA.
- Used specifically by DWAF personnel as a basis for negotiation with the mining industry, and likewise by the mining industry as a guideline as to what the DWAF considers as best practice in resource protection and waste management.
- Inform Interested and Affected Parties on good practice at mines.

The information contained in the BPGs will be transferred through a structured knowledge transfer process, which includes the following steps:

- Workshops in key mining regions open to all interested parties, including representatives from the mining industry, government and the public.
- Provision of material to mining industry training groups for inclusion into standard employee training programmes.
- Provision of material to tertiary education institutions for inclusion into existing training programmes.
- Provision of electronic BPGs on the DWAF Internet web page.



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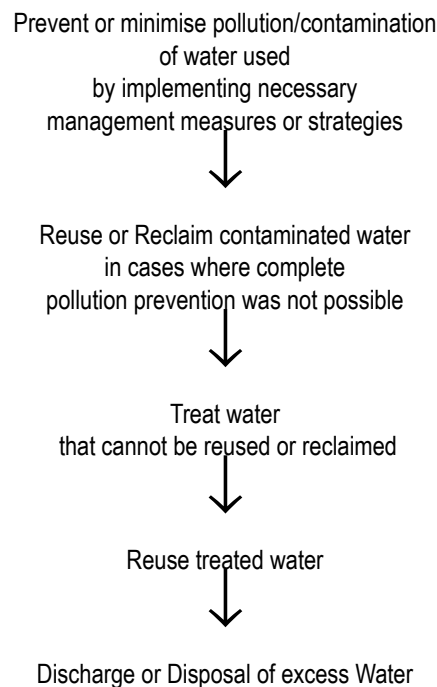
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## 1

## INTRODUCTION

Large amounts of water are consumed/used by the mining industry for transport of material (slurry), processing (washing, separation plants), control (cooling systems, boilers) etc. This water is abstracted directly (from boreholes, dams, streams or rivers) or indirectly (via water service provider) from water resources (surface and ground) and therefore may place strain on South Africa's limited water resources. Some of the water abstracted is lost through for example evaporation. Other raw water intake is contaminated during its utilization and therefore not fit for direct release/discharge back into the water resources it was taken from. Given the growing demand for water and the scarcity of this natural resource, it is important for any mining operation to prove that water utilisation is optimized by reuse and reclamation of contaminated water.

The basis of integrated water and waste management (IWWM) at mines is the Department of Water Affairs and Forestry (DWA) Resource Protection and Waste Management *hierarchy of decision-taking*. This hierarchy is based on a *precautionary principle* and sets the following order of priority for mine water and waste management decisions and/or actions:



All new and existing mines are, therefore, required to optimise water reuse and reclamation. The process or approach to be followed to establish a Water Reuse and Reclamation Plan for a new or existing mine would be the same though the implementation/execution may be different.

The Water Reuse and Reclamation Plan should ideally form part of the larger Integrated Water and Waste Management Plan (IWWMP) but in some instances may be developed as a stand-alone document. As a stand-alone document (in the absence of an IWWMP), the Water Reuse and Reclamation Plan may be used as motivation to DWA for a water use licence/authorisation to discharge and/or dispose of waste or water containing waste.

As water reclamation refers to the operational use of water, this Best Practice Guideline (BPG) will not have application to closed mines. Where desired, the reuse and reclamation of water decanting from closed mines could be considered on a case-by-case or site-specific basis;

however, the process/approach put forward in this BPG may not necessarily be the appropriate one to deal with closure cases.

Small or isolated process effluent streams may not be considered as feasible water sources due to the cost involved to divert small volumes over large distances to where it may be required/used.

Close inspection and evaluation of a mine's water and salt balance (see BPG G2: Water and Salt Balances) will indicate where scope for improvement exists. Improvement in the mine's Water Reuse and Reclamation Plan is possible where the following features are found:

- Wherever large volumes of water are used and/or disposed of (e.g. slimes dams and slurry dams).
- Wherever good quality water is imported into the water circuits while poorer quality water is lost (e.g. discharge, evaporation, seepage).
- Wherever good quality water (potable) is purchased/abstracted while water of a poorer quality is acceptable for use without compromising product yield or quality.
- Where the implementation of pollution prevention strategies does not result in the elimination of all pollution.

Conversely, if an inspection of the water and salt balance (prepared in accordance with BPG G2) does not reveal any of the above features, it is unlikely that there will be any scope to improve water reuse and reclamation.

As part of a mine's Water Reuse and Reclamation Plan and during investigation of opportunities for such, it is important to identify the water quality requirements for the mine and its different uses. Constituents of concern, i.e. constituents that can impact on product quality and yield or might interfere with mine processes, need to be identified.

From a conservation perspective, reuse and reclamation ensure effective and beneficial use of scarce water resources and overall environmental protection. Reuse of waste water internally on a mine is preferred to extensive treatment schemes (costly) to treat effluent prior to discharge in a water resource.

Water reuse and reclamation have the following benefits:

- Cost saving: Reduction in abstraction cost (e.g. water pricing) or purchase cost (water service provider) due to reduced raw water intake. Reduction in disposal cost (e.g. waste discharge charges) and treatment cost. The capital cost for reuse and reclamation is less than for treatment and operational savings can be maintained. Financial benefits will be one of the major driving factors for reuse and reclamation in the near future.
- Legal compliance: Meet legislative waste minimisation and water conservation policy goals.
- Limit liabilities: Reduce potential environmental liabilities by reducing releases (discharges etc) and impacts on the receiving water resource.
- Protect public health: Protect public health by preventing pollution of the water resource.
- Environmental protection: Protect the environment, specifically the water resources.
- Water conservation: Reduce raw water intake and therefore overall water consumption, working towards water conservation.
- Reclamation: Reclamation of materials/constituents with a severe impact on the environment and/or a high reclamation value.
- Public image: Improve image with public, surrounding communities and workers due to concern shown for the environment.

## DEFINITIONS

In order to facilitate communication among different groups associated with water management, it is important to understand the terminology used in this BPG and in the arena of water reuse and reclamation.

**Contaminant:** A property/characteristic that prevents/limits the direct reuse of a (waste) water stream. Contaminants include physical characteristics such as heat content (temperature), turbidity, colour, acidity (pH) and other constituents (chemical or biological).

**Fit-for-purpose:** This term relates to water quantity and quality. It is thus based on the water quality and quantity requirements of a specific mine water use. The term process water demand is often also used in the mining industry to refer to this.

**Process changes:** Replacing the technology employed in a process can reduce the inherent demand for water. Examples might be replacing an evaporative water cooling system with air coolers; replacing a wet scrubber on stack emissions with a baghouse system or increasing the number of stages in a washing operation. Sometimes it is possible to reduce water demand by changing the way existing equipment is operated, rather than replacing or modifying it.

**Process sink:** A process that only consumes water i.e. the stream leaving the process cannot be used as a water source for other processes. Evaporation (spraying for cooling or dust suppression) and water of a very poor quality are examples of such processes. Poor quality water, which cannot be reused directly, may become a source when treated or combined with or diluted by another water source.

**Process source:** Contains water streams and has a water discharge but the process does not have a raw water intake.

**Process unit operation:** Uses and discharges water such as the metallurgical plant. Thus has a water intake and outflow, not only a sink or a source.

**Water conservation:** Good housekeeping measures, cleaner technologies, process modifications and process optimisation (increase efficiency, reduce spillages, identification and management of risks of failure, etc.) all contribute to water conservation efforts. Water resources should not be depleted by continuous raw water intake but must be properly managed to maintain the continued existence of the aquatic environment, allow for sustainable development and associated water use and ensure the availability of water downstream for other uses.

**Water reclamation:** Treatment or processing of waste water to make it reusable. *Reclaimed water* is the treated effluent suitable for an intended water reuse application. Also see Figure 2.1.

**Water recycling:** Involves only one use or user and the effluent resulting from the use is collected, treated if necessary and redirected back to its original use or related application. Water recycling sometimes involves the inclusion of additional treatment or a regeneration step to remove the contaminants, which build up in the system. Water from one process (effluent) may be recycled back to that process without treatment but when it flows back into the process it might also contain water from other sources/processes, which is less or more contaminated. Recycling is thus water reuse in the same area; water is reused in the same process/area that it is produced/generated in. Also see Figure 2.1.

**Water reuse:** The use of waste water/effluent/contaminated runoff without additional treatment for other beneficial purposes. Waste water from one operation can be used in another operation on the mine, provided the level of contamination from the previous process does not interfere

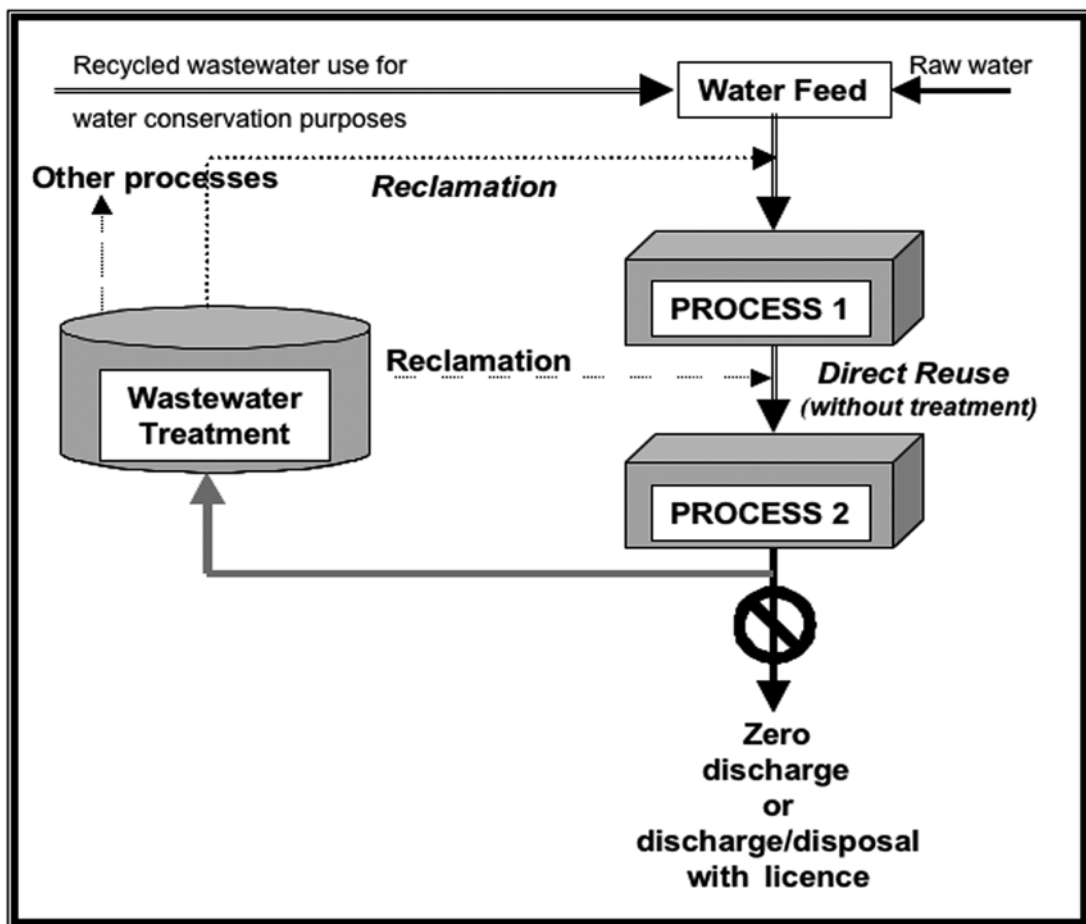
with the subsequent process. This is sometimes called cascading. The use of water in one process produced by another process is very common in mining operations since it is typical to find major water users and major waste water producers that are not necessarily linked in the processing. Water is used as is (without change in water quality). Typically the cost for water reuse consists mainly of piping or reticulation. Also see Figure 2.1.

**Direct water reuse:** requires the existence of pipes and other conveyance facilities for delivering reuse water. Water can be reused in the same area from which it was produced (recycling) or water can be reused in another area. Water from different areas is diverted to a central point (process water dam) from where it is reused/ recycled within the area of responsibility of the licensee (person in control).

**Indirect water reuse:** through discharge of an effluent to a receiving water body for assimilation and downstream withdrawal. Also includes the off-site reuse of water by a neighbouring property.

**Water Reuse and Reclamation Plan:** The water reuse and reclamation plan is intended to form an integral part of the Integrated Water and Waste Management Plan (IWWMP). However, the plan may also be used as a stand-alone document for the purpose of motivating a water use licence/authorisation to DWAF. The plan would be very site-specific based on the components and complexity of the mine.

**Figure 2.1: Schematic representation of the concepts of water reuse, recycling and reclamation**



**OBJECTIVES  
AND KEY  
CONSIDERATIONS**

### 3.1 Objectives of this Guideline

The development of water reuse and reclamation plans is typically undertaken for one or more of the following motivating reasons:

- To minimize the consumption (or purchase) of good quality water from outside (from a water service provider or from a water resource).
- To minimise the pollution effect of the mine and therefore its impact on the surrounding environment.
- To minimise water losses from the water reticulation system and maximise reuse opportunities.
- To save cost (water pricing and waste discharge charges will often drive this).

It is important to emphasize that the Water Reuse and Reclamation Plan must take account of the changing water and salt balance over the life cycle of the mine and it must therefore be sustainable, flexible and regularly updated to reflect the relevant changes in the activity (process changes etc).

The intent of this BPG is to assist in the development and review of Water Reuse and Reclamation Plans by meeting the following objectives:

- To clearly define the process that should be applied by a mine when developing a mine water reuse and reclamation plan and that will be applied by DWAF when reviewing/evaluating a mine water reuse and reclamation plan within the bigger context of the mine's IWWMP.
- To define a process that, when applied, will clearly indicate to DWAF that water reuse and reclamation have been applied effectively and that the mine may move to negotiations regarding discharge or disposal if required.
- To define the structure and content of a report or section of a report (section of IWWMP) or product that must be submitted to DWAF to enable the review/evaluation of the mine water reuse and reclamation plan or IWWMP.

### 3.2 Key Considerations

There are four key considerations that need to be applied in the development and implementation of a Water Reuse and Reclamation Plan.

- Pollution prevention consideration. Deterioration of water quality must be prevented wherever possible and minimised where complete prevention is not possible.
- Conservation consideration. Losses of water and consumptive use of water must be minimised.
- Water users within the mine must be provided with water of a quality as poor as possible but good enough quality that it does not cause significant user, water quality, product quality or process related problems (scaling etc).
- The plan must be sustainable over the life cycle of the mine and over different hydrological cycles.

Below a number of evaluation criteria have been defined for each consideration.

#### 3.2.1 Pollution prevention - Minimise deterioration in water quality

- Ensure that all possible opportunities for the prevention of water pollution have been identified and applied.

- Ensure that, in the case where pollution prevention is not possible, the necessary management measures are implemented to minimize impacts as far as possible.
- Ensure that water use practices do not result in unnecessary water quality deterioration.
- Minimise contact between water and major pollution sources where possible.

### 3.2.2 Conservation - Minimise water losses and consumptive use

- Prepare and evaluate a detailed water and salt balance (BPG G2) for the mine.
- Ensure that evaporative losses from “clean” water storage dams (limit exposed surface area) and evaporative cooling systems are minimised. In contrast, evaporation from pollution control dams containing process waste water may occur once treatment and reuse has been maximised. The cost associated with evaporation of water also needs to be considered. Limit evaporative cooling systems where possible and investigate other types of cooling systems (air etc).
- Limit evaporative cooling systems where possible and investigate other types of cooling systems (air etc).
- Ensure that seepage/overflow losses from storage facilities are minimised, e.g. facilities that can possibly seep should be lined, and storage facilities should be designed with sufficient capacity and operated at a level to allow it to accommodate storm events without overflowing or spilling (capacity requirements as stipulated by GN No 704).
- Purchase raw water only for processes requiring such good water quality and additional water requirements that cannot be supplied within the water network.
- Evaluate the process technology being used in terms of its water use requirements and whether or not alternative technologies could be applied (particularly important for new mines) or whether the technology could be modified or improved to reduce water consumption.

### 3.2.3 Provide Mine Water Uses with poorest allowable quality

- Establish clear and accurate water quality requirements for all mine-related water uses.
- Establish water quality constituents affecting/ impacting on product quality or yield and/or process

optimisation /performance.

- Optimally match uses with the required water, taking cognisance of economic and practical restraints with regard to having different water reticulation systems.
- Institute monitoring to ensure that adverse effects of unacceptable reclaimed water quality are not being manifested, i.e. corrosion, scaling, reduced process performance.

### 3.2.4 Sustainability over mine life

- Develop water and salt balance projections (BPG G2) for future mining scenarios, including mine closure and post-closure.
- Apply considerations 1, 2 and 3 to each projected water and salt balance and integrate the results into a coherent Water Reuse and Reclamation Plan that is valid over the mine's life-cycle.
- Long-term planning and sustainability should be considered and therefore predictions on water quality and quantity into the future should also be incorporated (predictive modelling) to ensure that reuse and reclamation plans are not affected by future processes.
- Document and motivate the integrated water reuse and reclamation plan for consideration by DWAF.

The application/implementation of the above considerations and evaluation criteria is presented in detail in Chapter 4 of this Best Practice Guideline. While the application of optimised water reclamation is considered essential best practice and is not negotiable, the detailed features of each mine's Water Reuse and Reclamation Plan will be site-specific and subject to negotiation with DWAF.



## 4

**PROCESS FOR  
DEVELOPMENT  
OF A WATER REUSE  
& RECLAMATION  
PLAN**

## 4.1 General

Water reuse and reclamation ensure effective use of South Africa's scarce water resources and therefore assist with water conservation and the protection of the water resources in general.

The process that should be followed in developing a Water Reuse and Reclamation Plan is shown in the flowchart in Figure 4.1 and discussed in detail in this section. This stepwise process allows for review at each stage/step. In addition, fully defining the problem and gathering required data in the initial stages ensures that future decisions are based on complete information. In turn, developing a list of possible options for consideration reduces the chances for missing the optimum solution.

The process set out in Figure 4.1 can be applied within a mineshaft area or metallurgical plant, or at a broader scale across a whole mine.

It is important to note that this is an iterative process. At various points in the mine development (life of mine), the Water Reuse and Reclamation Plan need to be re-assessed and evaluated as to whether it is still appropriate and suitable.

Water reuse and reclamation related activities over the life of mine typically include:

### Planning and feasibility phase:

- Undertake detailed planning and feasibility studies on the overall water balance, in consultation with design engineers.
- Evaluate different process designs in order to optimise the overall water balance and reuse/reclamation plan.
- Identify possible water sources.
- Determine water quantity and quality requirements based on process design.
- Investigate opportunities for water reuse and reclamation.
- Develop and compile Water Reuse and Reclamation Strategy/Plan.
- Compile and include above into Integrated Water and Waste Management Plan (IWWMP).

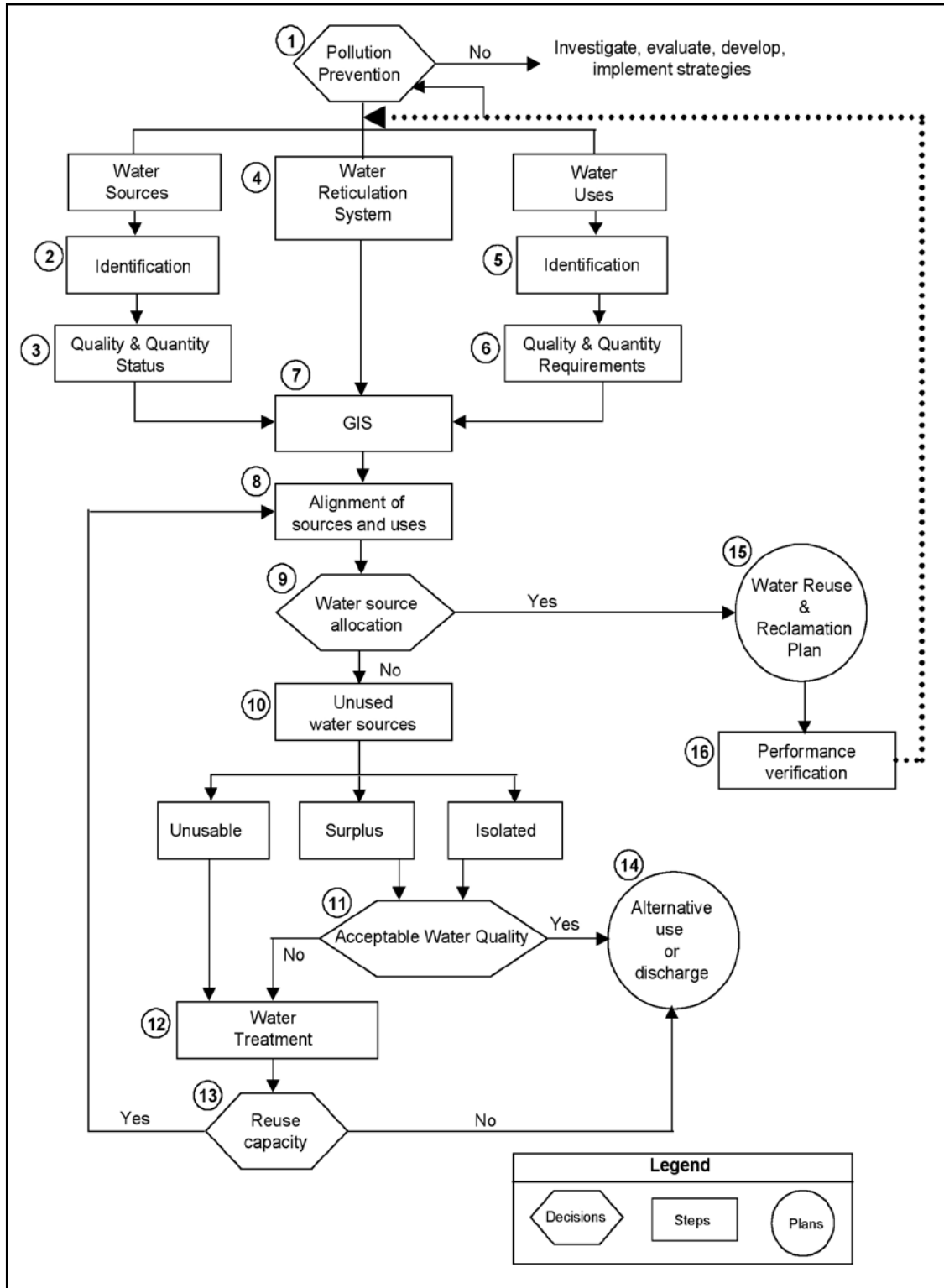
### Operational phase:

- Implement water reuse and reclamation strategy/plan.
- Continuous review and improvement of reuse and reclamation strategy/plan.
- Perform regular performance assessments and revise reuse and reclamation strategy/plan if required.
- Process technologies should continuously be evaluated in terms of their water requirements and whether modifications, improvements or new technologies can be applied to reduce these water requirements of water uses.
- Implement monitoring system to verify performance.

### Decommissioning and closure phase:

- Verification of latent/residual excess water quantity and quality (decant) through monitoring systems, performance assessments and predictive modelling.
- Define post-closure water reuse and reclamation options and determine best practicable environmental option, e.g. treatment and discharge, irrigation with decant water, sustainable development projects, etc.
- Finalise financial and contractual arrangements/agreements for post-closure water management and maintenance of infrastructure with future landowners and/or responsible parties and/or water users.

Figure 4.1: Flow chart for the process to develop a Water Reuse and Reclamation Plan



## 4.2 Planning Phase

Good practice in water management is based on the sequential consideration and application of the DWAF Resource Protection and Waste management hierarchy (refer to Section 1):

- 1 Apply pollution prevention or minimisation strategies at source.
- 2 Apply water reuse and reclamation strategies.
- 3 Apply waste water treatment strategies.

Experience has also shown that any Water Reuse and Reclamation Plan is more easily and cost effectively applied if pollution prevention strategies were applied first. Accordingly, before embarking on the development of a water reuse and reclamation strategy, it is considered advisable to first investigate, develop and implement appropriate pollution prevention strategies wherever possible, e.g. early recognition of the potential for acid drainage and the adoption of appropriate risk management strategies (encapsulation, selective handling, diversion etc.)

### 4.2.1 Step 1: Pollution prevention

#### **Purpose:**

To ensure that all pollution prevention strategies have been applied.

#### **Method:**

Investigate, evaluate, develop and implement appropriate pollution prevention strategies wherever possible, e.g. early recognition of the potential for acid mine drainage and the adoption of appropriate management strategies (encapsulation, selective handling, clean and dirty water separation, etc).

#### **Additional considerations:**

Ideally all pollution prevention strategies should have been implemented but this is usually an ongoing process. It might therefore be the case that all pollution prevention strategies have been considered but have not all been fully implemented as yet. In this case, it is acceptable to proceed to Step 2.

#### **Other sources of information:**

Refer to Appendix C for details on possible pollution prevention strategies to be considered.

#### **Decision:**

If after the investigation it is considered that all possible prevention strategies have been considered, evaluated and/or implemented where appropriate, then continue to Step 2. If not, reinvestigate the mine's pollution prevention strategy.

## 4.3 Water System

### 4.3.1 Step 2: Identify water sources

#### **Purpose:**

To ensure that all possible water sources, available on the mine, have been identified.

#### **Method:**

- Locate where processes are fed with raw water and establish where these processes are fed from (dams, boreholes, natural water bodies, service providers etc).
- Locate all water using processes including utility services and establish where their water originates from.
- Locate all points where (waste) water or effluent is generated.
- Locate all water or contaminated water storage and collection areas.
- Consider water quality, supply and volume (use data for the past 5 years if possible).

#### **Additional considerations:**

- Consider dividing mining activities into sources, sinks and unit operations (see definitions in Section 2).
- Raw water should only be purchased or abstracted for processes requiring such good water quality or where the water cannot be supplied within the internal water network.
- Future scenarios should also be considered and other water sources that might become available. This is especially relevant to new operations where water sources are limited at the start but as the operation proceeds more water sources becomes available (dewatering, captured storm water etc).

#### **Other sources of information:**

Detailed water and salt balance (BPG G2).

### 4.3.2 Step 3: Water source quality and flow status

#### **Purpose:**

To define the water quality and flow status as well as the variability of the possible water sources identified in Step 2.

#### **Method:**

Characterise the water streams/sources with respect to flow rate, quality and variability data through a monitoring system. Base the characterisation on information over the past 5 years, if possible.

#### **Additional considerations:**

- Quality is represented by the concentration of critical contaminants and constituents of concern.
- The effect of each process on the water it uses is represented by the load of contaminants (concentration multiplied with flow) that is transferred to the water that passes through it. Thus the difference between the load in and the load out.
- Water quality and quantity may change over time and during the life-cycle of the mine and this variability needs to be included (For example: start up operation for a particular process may require more water initially which could decrease with time when maybe only top-up is required; storm water volumes vary seasonally; tailings dam volumes and seepage quality will be influenced by management practices, processing and period in life of the mine).
- Determine and use statistically calculated values and rate of variation in flow and quality where significant variations can be expected over the life-cycle of the mine.
- Future predictions (over the life of mine, including post-closure) of water quality and quantity through predictive modelling should also be considered.
- It is also useful to sort all waste water streams into classes according to the effect they may have on the environment and the risk they pose.
- Flow measurements can be manual, on-line/in-line or ultrasonic (piping accessible and relatively clean on the inside). Point measurements are sufficient when absolute certainty exists that the water-using process considered operates on a continuous basis. For non-continuous or batch processes, flow measurements

have to be performed for a representative time frame. Software packages such as WaterTraker™ may be useful (minimize flow measurement campaigns by resolving data conflicts and completing the mass-balance by locating the best additional measuring points). Cleaner technologies or processes using less water also need to be considered.

#### **Other sources of information:**

- Water quality variations in key water streams will assist in identifying specific contaminants of concern. The detailed water and salt balance (BPG G2) would provide information on all the available water sources, their water quantities, water qualities and the variability of these.
- Monitoring of available water sources (BPG G3) will ensure that adverse effects of unacceptable water quality are not experienced (corrosion, scaling, etc). The crucial constituents of concern (for management) are dependent on the source (Step 2) and users (Step 5).

### 4.3.3 Step 4: Water reticulation system

#### **Purpose:**

To assess (identify and define) current/existing water reticulation systems.

#### **Method:**

- Assess current/existing water reticulation system.
- Identify opportunities for reusing effluent water from one process as influent water to another process.
- Establish where water reticulation networks may need to be installed or extended/modified once reuse pathways are validated.
- Check pipe sizes (diameter), pump rates etc with requirements.
- Assess adequacy of water storage facilities within the reticulation system and establish necessity of additional requirements.

#### **Additional considerations:**

Often only the simple rerouting or diversion of existing pipelines are required to connect one process with another, sometimes additional pumps and sumps may be required or an upgrade of the existing reticulation system is required. Consider practical and economic constraints.

#### 4.3.4 Step 5: Identify mine water uses

##### **Purpose:**

To identify all mine water uses, i.e. areas/processes on the mine requiring water for its operation.

##### **Method:**

- Conduct a water use inventory. A list of existing and potential mine-related uses needs to be compiled because water quality requirements are intrinsically linked and based on use requirements (Step 6).
- Identify both direct and indirect water uses. Water use on a mine can range from potable use to use for mineral processing, cleaning, dust suppression, transport, irrigation, etc.

##### **Additional considerations:**

- In the case of indirect uses, reuse needs to be consistent with the water resource management plan for the river basin or catchment (e.g. resource water quality objectives) and must consider downstream water rights, water use and user requirements.
- Process technologies should continuously be evaluated in terms of their water requirements and whether modifications, improvements or new technologies can be applied to reduce these water requirements of water uses. Thus, in reuse and reclamation, cleaner technologies should always be investigated and implemented.
- Water use practices should not result in unnecessary water quality deterioration.
- Future water use needs to be incorporated, e.g. additional shafts etc might be planned and needs to be considered to make the plan sustainable over the long-term.

##### **Other sources of information:**

The water quantity and quality required (Step 6) could also be established from the water and salt balance (BPG G2).

#### 4.3.5 Step 6: Water use quantity and quality requirements

##### **Purpose:**

To define water quality and quantity requirements of all mine water uses.

##### **Method:**

- Consider water quality parameters that affect/impact on product quality/yield and/or process performance/optimisation.
- Establish fit-for-purpose quality and quantity criteria.
- Consider the water quality needs of the mine-related use and not only the water quality currently supplied (For example: supply of potable water for a use that actually requires water of a lesser quality).
- Distinguish between direct and indirect water use and different requirements for these.
- Determine potential acceptance of water quality and quantity at proposed standards (without treatment). If unacceptable, determine additional treatment required to render water quality and quantity of an acceptable standard.
- Group uses with similar water quality requirements together to provide a number of different water quality groups/categories, which will meet all use requirements. These will be linked to key contaminants, specific applications or water uses.
- Aim to use water with the minimum amount of treatment.

##### **Additional considerations:**

- The biggest hurdle for many operational mines is often a basic lack of knowledge of the water aspects of plant processes, such as flow rates to individual processes, contaminant loads and minimum water quality requirements for individual processes. Flow and quality monitoring and the implementation of a sampling and analysis protocol are often required to supplement this missing data (BPG G3).
- Minimum water quality and quantity requirements for individual processes, e.g. metallurgical plant, can be specified in the design criteria. However, sometimes it is not possible to establish this at the initial step and laboratory testing may be required to establish the contaminant loads that can be handled. It is thus important to know at which point the concentration of a constituent becomes a problem to the effectiveness of the process or the quality of the product.
- Reuse or reclaimed water quality must be tailored to meet health and environmental requirements of particular applications such as the use of processing effluent for irrigation of a golf course, for example (requires a water use license/authorisation). Fitness-for-purpose can be linked to national regulations

and guidelines and the assessed risk is therefore not only a function of recycled water quality, but also the method of application, the local health and environmental circumstances, public acceptance and local economic circumstances.

- The same mine water uses might have different water quantity and quality requirements at different points within the mine life-cycle due to different mining methods or processes or product quality requirements. Thus, future predictions on water use requirements must be done on an ongoing basis to ensure a sustainable plan.
- On the other hand, different mine water uses might have similar water quality requirements (grouping).

#### **Other sources of information:**

- South African regulatory guidelines from health and water pollution control authorities, such as the DWAF Water Quality Guidelines (1996) for indirect or downstream use.
- Other international guidelines or quality criteria (World Health Organisation etc).
- Australian National Guidelines for use of recycled water (NHMRC 2000) based on health risk criteria (degree of contact).
- Californian treatment and quality criteria for non-potable uses of recycled water based on health risk criteria (Title 22 Regulations, 2000).
- USEPA (1992) guidelines for reuse of municipal waste water based on health risk criteria.
- WHO guidelines for use of treated waste water for agriculture and aquaculture (1989).

#### **4.3.6 Step 7: Geographically referenced plans**

##### **Purpose:**

To develop geographically referenced plans showing water sources, water uses and existing reticulation system(s) in order to assist linking these. This will support effective water and waste management and the compilation of accurate water and salt balances for the mine.

##### **Method:**

- Create a flow sheet model (schematic flow diagram) of the water reticulation system(s).

- Select an appropriate tool to use for data and information management.
- Validate reliability of data before entering into the information management system.

##### **Additional considerations:**

- The systems used can be simple and can vary from Excel spreadsheets to complicated computerised models depending on the size of the operation and the application. It should be user-friendly and appropriate for the specific circumstances and users.

## **4.4 Water Reuse and Reclamation**

### **4.4.1 Step 8: Aligning water sources to water uses**

#### **Purpose:**

To align and allocate water sources to water uses, taking into account all previous steps.

#### **Method:**

- Align and allocate recycled water quality and quantity to various applications or water uses.
- Achieve the minimum use of raw water or optimal flow configuration in the particular system of operations.
- Optimise the water reticulation system as far as possible. Conceptual designs derived from water allocation analysis steps (Appendix B) must be comparatively evaluated to choose the best option. The alternative analysis includes an evaluation of technical, monetary, environmental and social factors.
- Ensure true and accurate cost analysis since decisions are based on financial considerations.

#### **Additional considerations:**

- For the first operational sequence, no effluent may be available for reuse and consequently raw water may have to be abstracted for the early processes in the sequence, irrespective of quality considerations (especially true for new mining activities).
- It is possible to use effluent from previous cycles for later cycles, if provision is made for storage (refer to Step 4).

- The effluent from one process can be used as influent to another process through rerouting the reticulation system (refer to Step 4), which requires little capital investment (piping).
- Pipe sizes will assist in identifying whether capacity exists for additional volume or not.

**Other sources of information:**

Appendix B provides tools to assist with the alignment of water sources and uses:

- Water reuse ladder
- Water pinch analysis

#### 4.4.2 Step 9: Water source allocation

**Purpose:**

To determine whether all water sources have been allocated for reuse.

**Decision:**

- If at this point in time all water sources have been allocated to a specific water use, i.e. all recycled water has been reused; the mine can complete its Water Reuse and Reclamation Plan (Step 15).
- If however this is not the case, and there is still surplus water that has not been allocated for reuse, proceed to Step 10.

**Additional considerations:**

It is important to ensure that all mine-related water uses are receiving the worst allowable quality water (refer to Step 6).

#### 4.4.3 Step 10: Define unused water sources

**Purpose:**

To define the unused water sources, i.e. reason for not being allocated to a specific water use during Step 8.

**Method:**

- Categorise the unused water in terms of the reason for not being allocated to a specific water use for reuse. Generally the main reasons for not being allocated are:
  - Water source is of too poor quality, for reuse by any of the identified mine water uses.

- There is a surplus of water, i.e. more water generated in the process than what could be reused.
- Water source is either too small or isolated to be incorporated into the water reticulation system.
- In the case of unusable water due to water quality constraints, proceed directly to Step 12. In the case of the other reasons, proceed to Step 11.

**Additional considerations:**

Other reasons for not allocating the water sources to a specific mine water use for reuse in the system could be identified by the mine. Examples are agreements for water supply with local communities or neighbouring farmers, forced releases as a result of licence conditions, etc.

#### 4.4.4 Step 11: Acceptable water quality

**Purpose:**

To determine whether the unused water is of acceptable quality to allow alternative use or discharge/disposal.

**Method:**

- Establish discharge limits and points in consultation with DWAF based on resource water quality objectives and downstream water user requirements.
- Evaluate the surplus and/or isolated water sources with respect to water quality.

**Decision:**

- If the water quality is acceptable, proceed to Step 14.
- If the water quality is not acceptable, proceed to Step 12.

#### 4.4.5 Step 12: Water treatment

**Purpose:**

To identify and investigate the relevant water treatment alternatives that are available based on target criteria (flow and quality requirements).

**Method:**

- Consider water quality and quantity requirements for water use (Step 6). Consider contaminants causing adverse effects such as corrosion/scaling, affecting/



impacting on product quality/yield and affecting/impacting process performance.

- Identify and investigate water treatment options.
- Determine process reliability. Consider whether the planned treatment process has been used for a similar situation/application. Reliability is particularly important if treatment facilities will be part of the production process. Also consider cleaner technologies (such as baghouse systems rather than wet scrubber systems) as these become available.
- Evaluate all side streams from the treatment process to ensure that all costs and impacts are known (handling and disposing of sludge, etc).
- Established whether it would be more appropriate to treat effluent streams simultaneously or separately based on characteristics/contaminants of concern.
- Evaluate type and optimal placement of treatment process to achieve the desired trade-off between performance, reliability, capital expenditure, operating costs, environmental impact and waste generated. May include laboratory/pilot plant testing to gather additional information.

**Additional considerations:**

- BPG H4 for overview of water treatment options to treat contaminated mine water.
- Balance risk and affordability. Consider what the minimum requirements and costs are to achieve the desired effect.

**Other sources of information:**

BPG H4 on water treatment

**4.4.6 Step 13: Determine reuse capacity after treatment**

**Purpose:**

To determine whether the treated water could be reused within the mine water system.

**Decision:**

- If after treatment, the water has a reuse capacity based on the previous work, proceed back to Step 8 for alignment and allocation of the treated water.
- If the treated water cannot be reused within the mine water system, proceed to Step 14.

**Additional considerations:**

- Ensure that the treated water is of acceptable quality before proceeding to Step 14 (refer to Step 11).

**4.4.7 Step 14: Alternative use or discharge**

**Purpose:**

To investigate alternative use or discharge options.

**Method:**

- Two options can be considered if not all water can be reused in the system:
  - Identify alternative users (off-site or downstream) for this water.
  - Discharge or dispose to the environment with an appropriate water use licence/ authorisation.
- Evaluate the alternative options with respect to technical feasibility, cost, environmental impact and long-term sustainability.
- Determine the best practicable option based on specialist investigations (if necessary) and an environmental risk assessment.
- Discuss options with DWAF and obtain the necessary approval, whatever the final decision may be.

**Additional considerations:**

- When the mine approaches DWAF, it should be able to prove that it has exhausted all other water management options and has no alternative but to discharge/dispose. It is therefore important that all alternative uses be identified and evaluated prior to applying for a water use licence/authorisation to discharge/dispose.
- A neighbouring industry or mine could use the water, thereby preventing discharge/disposal to the environment and additional consumptive raw water use by the neighbouring industry.
- Depending on the water and its constituents, it may be of use to Small, Medium and Macro Enterprises (SMME). For example, it may not be economical for the mine to recover valuable metals from the stream due to small flows or low metal concentrations and high associated cost but SMME might find it cost-effective due to the size of its operation. This concept of reuse between different industries in the same area/catchment should also be explored to evaluate water

management options on a catchment basis. The interdependence/symbiosis is based on the idea that one company's waste product is another company's raw material.

- A mine's long-term objective/goal should be to reach a stage of zero discharge and any mine should progressively work towards this. Additional measures that can be taken over the short to medium term to achieve this include application of new production processes (cleaner production/technology), application of alternative raw and aid materials, process modifications, process optimisation, decentralised water treatment for reuse purposes, good housekeeping measures, end-of-pipe measures (waste water treatment).
- During the decommissioning and closure stages of the mine, when the mine no longer requires water for operational activities, consideration should be given to either treatment (if required) and discharge or an alternative (indirect) water user (farmer, neighbouring industry etc) of any excess water and/or decant.
- The implications and liabilities associated with the supply of water from the mine to an outside/other user (cross-industry liability) should be considered and the required legal documentation should be incorporated. The parties involved should agree on the period of supply as well as the quantity and the quality of the water supplied to the user. These agreements should become legal documents.

#### 4.4.8 Step 15: Water Reuse & Reclamation Plan

##### **Purpose:**

To develop and implement the Water Reuse and Reclamation Plan.

##### **Method:**

- After completion of the process described in Steps 1 to 14, the mine can complete its Water Reuse and Reclamation Plan. The Water Reuse and Reclamation Plan could be included in the overall IWWMP for the mine, or completed as a stand-alone document, depending on its purpose.
- The methodology and process followed during the development of the plan must be described in detail and all other relevant plans and/or procedures (such as the water and salt balance) must be revised in

accordance to the Water Reuse and Reclamation Plan.

- The reuse and reclamation plan should address the whole life of mine, including decommissioning and post-closure.
- The reuse and reclamation plan for a new mining operation will still be conceptual with long-term commitments and actions for closure.
- An existing operation, approaching closure, will have detailed plans for reuse and reclamation of excess water post closure.
- Develop an action plan for the implementation of the Water Reuse and Reclamation Plan.
- Develop measurable, quantifiable performance indicators for the Water Reuse and Reclamation Plan.
- Develop a performance verification plan to monitor the implementation process and verify the success thereof (Step 16).

#### 4.4.9 Step 16: Performance verification

##### **Purpose:**

To verify and review the success of the implementation process through its performance.

##### **Method:**

- Implement a monitoring and auditing programme.
- Evaluate the performance of the Water Reuse and Reclamation Plan (comparison of actual and planned performance based on performance indicators).
- Verify and review plan regularly, especially if any changes in activities/processes have been made.
- Implement corrective actions, if necessary.
- Modify, revise or correct plan where necessary (corrective action requires going back into the loop). Refer to Figure 4.1; the process is an iterative process to ensure conditions improve.

##### **Additional considerations:**

- The development of a Water Reuse and Reclamation Plan is an iterative process. At various points during the mine life-cycle, the Water Reuse and Reclamation Plan needs to be re-assessed and evaluated as to whether it is still appropriate and suitable. Refer to Figure 4.1; the process is an iterative process to ensure conditions improve.

# 5

## LEGAL AND REGULATORY ROLE OF WATER REUSE AND RECLAMATION

Although a mine is required to implement the principles of IWWM and reuse/recycling throughout its life cycle, there is no legal or regulatory obligation for a mine to produce a Water Reuse and Reclamation Plan or an IWWMP (unless required in terms of licence conditions as provided for in section 41(2)(a) of the NWA). Currently the legally required documents associated with water reuse and reclamation and IWWM are the Environmental Management Plan (EMP) and water use licences/authorisations.

If the mine chooses not to produce a Water Reuse and Reclamation Plan, it will still need to incorporate the principles and elements covered in this document in the submitted EMP, water use licences/authorisations, etc. However, practical motivation for such a plan is clear as access to such a documented integrated plan will greatly assist the mine in meeting its obligations in terms of the various environmental laws and regulations that affect water and waste management over the full life-cycle of the mine.

Further, if a mine adheres to this BPG and others in this series as well as the principles of IWWM it will be considered to have met the DWAF requirements in terms of source directed regulatory measures.

6

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## APPENDIX A WORKED EXAMPLE

A simplified case study of the described reuse/reclamation process is provided below. The example focuses on one aspect of mining (metallurgical plant) since considering all aspects of mining could become very complicated and require extensive detail. The applicable principles/considerations are the same for all aspects and the purpose intended here is not to provide an extensive detailed discussion but only to demonstrate the principles/concepts and how they should be applied.

### Scenario

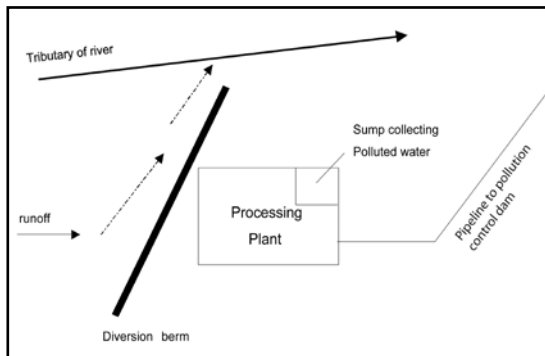
The mining and processing operation/facility under discussion has the following characteristics:

- Operational period: 7 years
- Life of mine: 20 years
- Rainfall in the area occurs in the summer
- Manage information on a GIS based system
- Available potable water supply
- Available municipal water supply (treated water)
- Tributary of river running through the mining property, but the mine has no water use licence/authorisation to abstract water
- Low groundwater table with low water yields
- Diversion berms to divert clean storm water away from pollution sources
- Bund walls to contain pollution in heavily polluted areas
- A polluted water diversion network
- Pollution control dams are lined to prevent seepage from reaching surface and groundwater resources
- Pump station and reticulation system to pump slurry from plant to tailings facility
- Plant located 1 km from tailings dam
- Tailings drainage network
- Canal and return water dam (RWD) for tailings water management
- No process changes anticipated in the next 3 years
- Only seasonal variation of water quality and quantity

### Pollution prevention

All possible measures to prevent the pollution of clean water have been implemented. This includes:

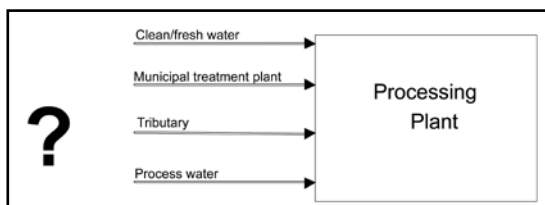
- separate water management systems for process water and storm water,
- the construction of diversion berms to divert clean storm water away from pollution sources such as the processing plant area,
- the construction of bund walls to contain pollution in heavily polluted areas,
- a polluted water diversion network (including drains, pipes, sumps, pumps etc) to ensure all polluted water (wash water, spillages, process water etc) is captured and diverted to its intended destination (pollution control dams),
- the lining of polluted water dams to prevent seepage from contaminating groundwater, etc.



### Water sources

The following water sources were identified:

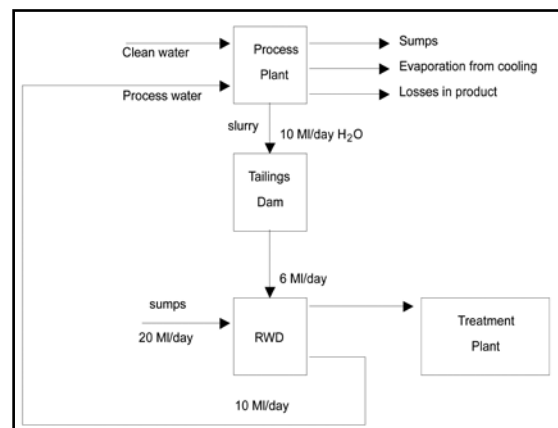
- Raw water from the bulk water supplier in the area. Potable water can thus be purchased, but is very costly due to good quality.
- Reclaimed (treated) municipal water from a municipal treatment plant can be purchased at a lower cost than potable water.
- Water from a tributary of a river that runs through the mine property can be abstracted. However, the mine does not have a water use licence/authorisation to abstract the water.
- Process water leaving the circuit (metallurgical plant effluent) of the mine can be treated (return water dam located next to the tailings dam) to an acceptable quality for reuse.
- Captured contaminated storm water.
- Groundwater is not considered a source due to the potential lowering of the water table in the area and its limited yield and recovery capability. Quantities are already insufficient for farmers in the area, especially during dry winter months.



### Water source quality & flow

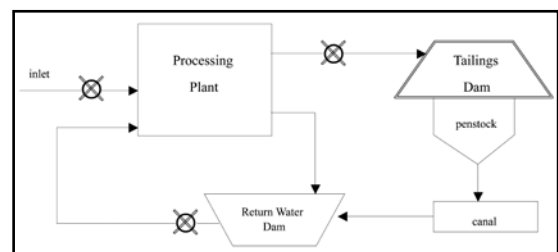
The mine has been operational for 7 years. The processing facility is thus fully operational with little changes anticipated in the near future. All major problems have been sorted out and operations run rather smoothly.

Flow of water and water quality therefore remains rather stable with limited variations apart from seasonal fluctuations. Variation in quantity is mostly seasonal, i.e. water volumes increase during the wet summer months in certain areas where runoff is considered contaminated /polluted and therefore collected. Water quantities thus increase in summer but the trends are quite predictable and consistent with rainfall variations. More dilution is then available to spills etc and the water quality improves slightly for certain contaminants such as sulphate. However, due to large volumes of water, more suspended solids are washed away and is carried into the pollution control dams.



### Water reticulation system

The existing reticulation system includes a pump station connected to a reticulation system to pump slurry (waste water and tailings) from the plant to a tailings dam 1 km away. The tailings dam has a drainage network (toe drains, penstock) that collects/recovers water from the tailings dam after suspended solids have settled out and the recovered water flows in canals to a lined dam (called the return water dam). The dam has a pump station on its western side that is linked with a second pipe network that feeds the water back to the plant. There is a large open space next to this dam.



## Water uses

The focus of this example is on the metallurgical plant as

a water use for the transport of its tailings (waste/residue

material) to the tailings dam and other processing steps

such as the washing of the material, separation, etc.

## Water use requirements

Water quality requirements for the transport of tailings are not very strict and rather poor quality water can be used for this purpose. Suspended solids in the water should however be limited. The water required for other processing steps in the plant need to be of a better quality but not necessarily of a potable quality. High heavy metal concentrations can interfere with the processing and very high salt concentrations can lead to scaling of equipment and pipes. Water with a low sulphate (< 200 mg/l) and heavy metal concentration (< 1 mg/l) is thus required for use in the processing plant.

## Geographically referenced plan

A GIS system has been set up at the mine and all the necessary information including layout of the site has been included.

## Alignment of water sources with uses

The return water dam collecting the recovered water draining from the tailings dam also receives water from other areas of the mine (sumps from plant area, etc). The quality of the water in the dam is poor with some dissolved heavy metals and high salt concentrations. Water entering the dam also has a high suspended solid content, but as the size of the dam allows water retention of approximately 48 hours and water movement in the dam is not vigorous, suspended solids can settle out. Much of this water (after settlement of suspended solids) gets pumped back through the existing reticulation system to the plant area to be reused for the transport of tailings since water quality requirements for this purpose are not strict. It can be safely said that the plant is receiving the worst water quality available (high salt and metal concentrations) for the transport of tailings.

## Water source allocation & defining unused water

However, not all water from this dam gets reused for the transport of tailings. The demand is lower than the available supply and a dramatic rise in the water level of the dam has been experienced during the last rainy season. The operating level is currently too high in that sufficient capacity is not available (according to the requirements of GN No 704) to allow for a storm event and prevent the discharge/overflow of dirty water to the natural environment.



More water is thus available for use; however, due to its poor quality the water cannot be used within the plant for other purposes. Treatment is therefore required to yield water of an acceptable quality for reuse in the plant area.

The purchasing of water of a good quality is expensive and this raw water quality is better than what is really required by the process. Water usage can become a considerable cost consideration in the production process.

The abstraction of water from the tributary will affect the water quality and flow in the river it feeds and therefore impact on downstream users and the aquatic reserve. Based on approved allocations to downstream users and the reserve determination, the authorities indicated that they would not issue a water use licence/authorisation to the mine to abstract water from the tributary since the catchment would be adversely affected.

Treatment was therefore the only remaining option to investigate.

### Water treatment

The process would involve the reduction of sulphate ( $\text{SO}_4^{2-}$ ) to sulphide ( $\text{S}^{2-}$ ) using an electron donor (ethanol, hydrogen gas). Metals will then be precipitated as metal sulphides. This will yield water with reduced sulphate and metal concentrations and the quality will be acceptable for reuse in the plant. The process is a proven process but some minor design parameters were confirmed through laboratory and pilot scale studies. A plant was to be erected on the open piece of land next to the return water dam for the treatment process.

The waste products of the process (a sulphur slurry and a metal sulphide sludge) would have to be considered in terms of their disposal or for recycling. An alternative process in which lime ( $\text{Ca}(\text{OH})_2$ ) is used for neutralization to produce gypsum ( $\text{CaSO}_4$ ) and metal hydroxides were also considered but was found to not reduce the sulphate concentration sufficiently due to the limitation associated with gypsum precipitation. Specialist studies and investigations were undertaken to assess the feasibility of the process. The necessary applications were made with the authorities and the mine is awaiting approval to go ahead.

Treatment provides a longer-term financial benefit since less abstraction from valuable water resources is needed and as all the dirty water in the system was reused and

reclaimed successfully, no discharge of polluted water into the natural environment was required.

### Water Reuse and Reclamation Plan

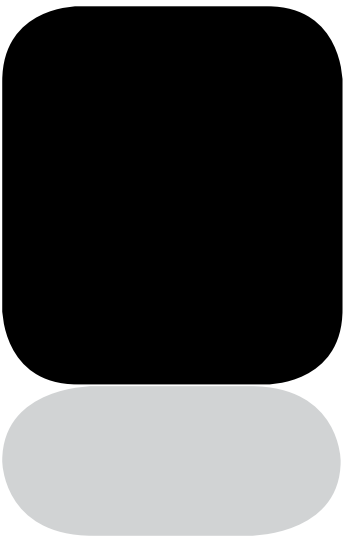
After approval by the authorities, the mine implemented the Water Reuse and Reclamation Plan successfully. The following performance indicators were set for the process plant:

- 10% reduction in raw water intake per annum
- Zero discharge to the natural environment

### Performance verification

The effectiveness of the Water Reuse and Reclamation Plan was verified by monitoring. A 20% reduction in raw water intake was achieved within the first year and this resulted in a significant cost saving. The capital and operating cost was found to be recoverable over a period of 10 years. The successful implementation of the Water Reuse and Reclamation Plan resulted in an overall environmental benefit as less raw (clean) water was abstracted for industrial purposes and the reuse/reclamation of the dirty water resulted in a zero discharge facility.

The Water Reuse and Reclamation Plan is reviewed on an annual basis and revised when necessary, or when any changes in the process technology and/or water reticulation system take place.



## TOOLS FOR ALIGNING SOURCES WITH USES

(refer to Wang, Y.P. and Smith, R. 1995b. Time Pinch Analysis. *TranslchemE*, 73a, pages 905 – 914; Ujang, Z, Wong, C.L, Manan, Z. A. 2002. Industrial waste water minimisation using water pinch analysis: a case study on old textile plant. *Water Science and Technology, Water Quality and Environmental Management in Asia*, 11 – 12 2002, volume 46, pages 77 – 84; Baetens, D. *Water Pinch Analysis*.)

### Water Reuse Ladder Concept

This approach involves generating a number of water reuse ladders. Each “step up” or interval of the ladder represents increasing contaminant load set by the individual processes. A different ladder is constructed for each time interval. The waste streams that are then available for reuse within that particular time frame are then grouped into their respective subintervals based on their quality and quantity characteristics. Any volume surplus in one subinterval can be reused in a higher concentration interval, in the same time interval, or stored for reuse in a later time interval. It cannot be used in lower concentration intervals, either from the same or previous time intervals or from raw water. The eventual cumulative surplus becomes the mine effluent and the accumulated raw water makes up the mine system’s intake.

### Water Pinch Analysis

**Definition:** - This is a water management/minimization tool that is used to identify the theoretical minimum raw water requirements and minimum waste water effluent for a given set of water using processes. A pinch analysis requires specification of the minimum inlet water quality requirements and maximum outlet water quality requirements for all water using processes. The pinch analysis will also lead to the identification of the *pinchpoint*, which is the bottleneck in the effluent/water network, and which sets the minimum water requirements for the network of processes. The pinch point might correspond to the quality of the inlet water, the outlet water (final effluent) or some intermediate quality.

It is therefore a systematic technology for analysing water networks to identify water reuse opportunities and reducing water cost. The pinch analysis requires specification of the minimum inlet water quality (Water user water quality – Step 5) requirements and maximum

outlet water quality (Water sources water quality – Step 3) requirements for all water using processes, referred to as the limiting process data or limiting water profile.

Water pinch analysis is a graphical targeting method. The pinch diagram is constructed by considering the process requirements or constraints, and not the current effluent flows and qualities. The limiting process water data or target data defined in Steps 3 and 5 is plotted on a graph. The graph has purity (water quality) on its vertical axis and water flow rate (quantity/mass flow) on its horizontal axis and is sometimes referred to as a purity profile or composite curve.

The input water streams of all water using operations are plotted in a “Demand Composite” to define water demand. The output water streams of all water producing processes are plotted in a “Source Composite”.

The horizontal overlap between the source and the demand curve shows the potential for water reuse (matching water sources with water demand) and guides the user to identify design options.

The overlap is limited by the pinch point (the point where the two curves touch). The open parts to either side of the overlap represent targets for minimum raw water consumption and minimum waste water discharge. Maximizing the reuse of water within the area between the two curves will automatically result in the minimum raw water makeup and waste water discharge.

Although very simple to use, a water pinch analysis can become complicated in systems with many streams and multiple contaminants. This process requires additional optimisation for one contaminant at a time. Then the result of every analysis has to be integrated to find the overall optimum solution. It is recommended that a specialist and commercially available software such as WaterPinch™ (Linhoff March's approach) be used. Application has resulted in 15-40% raw water savings and 20-50% waste water savings. For a water pinch example see IWA, 2002, pages 211 to 219.

Two different approaches will be adopted when undertaking a pinch analysis for a new system versus an operating system. These are discussed below.

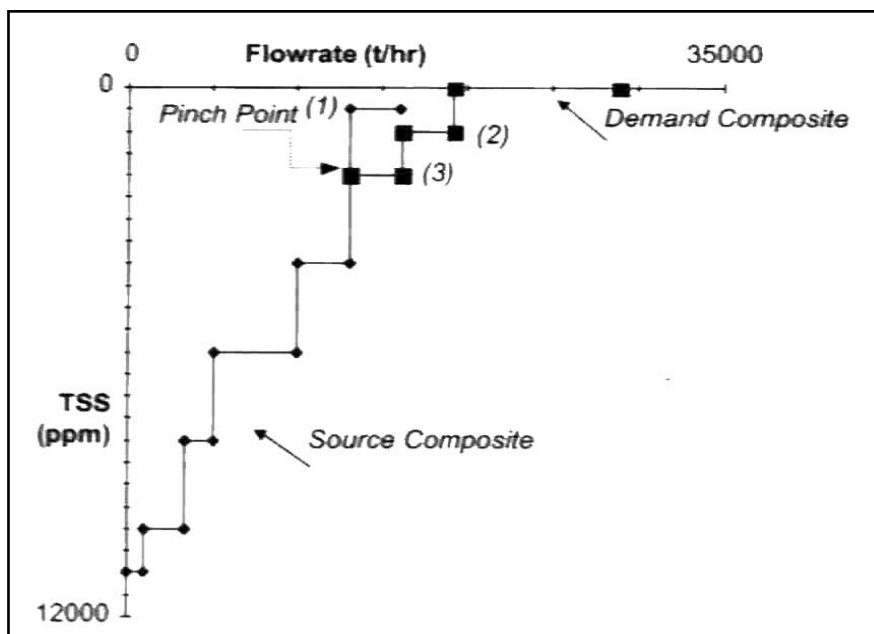
### New System design

Design specifications will usually provide limits or targets on the contaminant levels for each process, together with contaminant loads introduced by each process. From this

data, a composite water demand curve can be plotted on concentration/contaminant load axes (Wang and Smith, 1994), which allows determination of the minimum raw water supply which is able to satisfy all the process requirements, using *water reuse only*. This minimum water requirement is called the *target*, and the critical process concentration limit, which prevents any further reduction of the target, is called the *pinch-point*.

Once the pinch point and the target supply have been determined, it is relatively straightforward to design a water reuse cascade, which will achieve the target. The resulting network of flows between the operations can then be evaluated in terms of cost, practicability and operability and trade-offs established between water use and other such engineering criteria. Only at this stage should the use of regeneration processes be considered, and their only justification in the overall scheme will be to *overcome the limitation imposed by the pinch point*, so as to further the water supply target. Thus it can be demonstrated that to offer any benefit to the system, a regeneration/treatment process must take water of a quality worse than the pinch concentration, and regenerate it to a quality better than the pinch concentration. This is referred to as *appropriate placement* of the regeneration/treatment process.

Figure B1: Example of limiting process data for steel manufacturing operations



**APPENDIX C  
CONSIDERATIONS  
FOR POLLUTION  
PREVENTION AND  
WATER TREATMENT**

Note that the list is not exhaustive and only provide a few options that could be considered for pollution prevention.

**Pollution prevention:**

- Separation of water systems. Separate clean and dirty water systems to maximise reuse.
- Construct runoff diversions to divert clean runoff away from major pollution sources – berms etc.
- Use cut-off drains to separate clean and dirty sub-catchments in a mine area.
- Bund areas with major contamination sources. The water and spillages within the bunds should drain to a sump with a pump. The pump should be used to recirculate and keep water within this circuit. Prevent contact of water from bunded areas with other water on a mine site.
- Maximise closed circuits (bunded areas) where possible to minimise pollution and prevent impacts.
- Roof areas where rainwater infiltration poses a problem, such as chemical storage areas.
- Concrete areas to minimise seepage to groundwater and maximise storm water runoff.
- Slope areas to ensure effective and efficient storm water runoff.
- Contain all water contaminated by the mine including storm water, seepage, spillages etc. Seepage may require abstraction for reuse.
- Line all containment facilities used to store contaminated water with an appropriate lining (see Minimum Requirements).
- Use a leachate detection system for the early detection of liner failures.
- An under drain and seepage collection system should be installed for containment facilities to allow for the interception and reuse of seepage.
- Construct paved or concrete channels or drains for the conveyance of water (storm water and process water systems separate).
- Minimise dust and erosion, which add to suspended solid contamination of water through seeding or planting programmes.
- Prevent erosion or flood damage especially at outlets (channel or conduit for releases/ discharges) through installation of rip-rap or other methods to reduce flow velocity and dissipate flow energy and in doing so also protect and stabilise areas.
- Construct level spreaders to convert concentrated runoff to sheet flow and disperse it uniformly across a slope in areas where erosion can be a problem.
- Divert sediment-laden runoff to grit/sediment traps for the capturing and removal of suspended solids. This is especially important and relevant prior to the inflow into water storage dams since silt will reduce the dam storage capacity